V c RIV Measurements

INSULATOR RECOMMENDATIONS

LOCKE INSULATOR CORPORATION, BALTIMORE, MARYLAND

NOTES ON RADIO INTERFERENCE

Introductory Remarks:

All forms of radio communications are based on establishment and propagation of electro-magnetic waves in space. These waves when properly controlled or modulated may be used to transmit signals, intelligence or entertainment in a large variety of ways. The most familiar form is found in the present day commercial broadcasting of entertainment and news. In order to avail himself of these facilities the listener must provide himself with a suitable antenna for intercepting the electro-magnetic waves propagated by radio broadcasting stations. These waves cutting across the conducting antenna, induce feeble alternating voltages in it with reference to ground potential. These voltages, by means of a suitable receiver, may be amplified, rectified and converted into audible sound or other intelligible signals, according to the purpose intended.

Since the antenna to some degree responds to all electro-magnetic waves which cut across it, the receiver must have a means of selecting the one desired, and must be of sufficient sensitivity to respond adequately to the signal to be received. Because of the relatively small magnitude of the voltages induced in practical antennas, the receiver must be an extremely sensitive device capable of responding to almost infinitesimal voltage changes in the antenna. Accordingly it will respond to all electro-magnetic disturbances which cut across the antenna and which have frequency components corresponding to that to which the receiver is tuned. It is for this reason that the radio frequency spectrum (range of frequencies useful for radio communication) is divided into channels, by governmental control and international agreement. These channels are allocated with suitable power levels to broadcasting and other forms of communication to prevent what would otherwise be a choatic condition which would render radio communication impossible or at least unreliable.

It is unfortunate, but nevertheless true that a large variety of unwanted electro-magnetic disturbances either occur in nature or are incidentally produced by many devices which have come to be necessities to the modern mode of living. These may interfere or mar the reception of the desired signals. Natural disturbances (usually referred to as atmospheric static) of which lightning is the most common variety, are caused principally by electrical discharges in the atmosphere. Lightning strokes produce and propagate electro-magnetic disturbances having frequency components throughout most of the useful radio spectrum. With the established system of broadcasting there is little that is now known that can be done to eliminate this source of interference except to improve transmitting and receiving equipment and attempt to improve the strength of the desired signal in relation to the unwanted one. Other types or systems of broadcasting, such as frequency modulation, now mainly confined to ultra high frequencies, practically eliminate natural static and much that is man made. General acceptance and change-over, if ever, to frequency modulation is still several years away on account of the tremendous investment we have in amplitude modulation broadcasting stations and receivers.

Man made static can be practically eliminated by the exercise of the proper care in the design, manufacture, operation and maintenance of electrical apparatus and devices. In some cases simple suppression means can be employed to reduce or eliminate noise from devices which are inherently offenders. Any electrical device, which exhibits visible and audible electrical discharges in operation, such as sparks, streamers or corona is a potential source of radio interference. In fact, wherever air or other insulation is overstressed so that corona or sparking occurs radio interference may result. Hidden voids in insulators or insulations may also give rise to interference if the air or gas contained therein is under heavy electrical stress. In such a case the corona or discharge may be hidden so that it will be neither visible or audible. The reason that such discharges may cause radio interference lies in the fact that they represent sudden changes in the electrical characteristics of the device. Such changes in characteristics are always accompanied by small but sudden changes in current flowing to the device from the source feeding it. These sudden changes in current are always followed by a transient oscillation at a frequency determined by the inductance and capacity of the circuit through which the oscillation occurs. Usually these transients have frequency components in the radio frequency spectrum. Such a current transient generates a radio frequency voltage in the circuits associated with the device in which it originates, and these circuits may communicate these radio frequency voltages to radio receivers connected or coupled to them.

In other words a device, an insulator for example, which at the operating voltage across it, has corona or static discharge on its conductor or tie wire grooves, at the joints between shells, in the pinhole, or in fact has over stressed air anywhere around it, becomes in effect an inefficient but nevertheless annoying frequency converter or transmitter. It receives a small amount of energy from the line it supports at sixty cycles and converts it partially into a high frequency voltage having a very irregular wave shape with numerous sharp peaks. This voltage which is fed back into the line conductors by the insulator will have frequency components which extend throughout the broadcast band (550- Kc to 1550- Kc) and over into the long and short wave bands also. With most insulators the highest radio frequency voltages produced are usually in the frequency band between 550- Kc and 1000- Kc, and the effect decreases rapidly in the higher frequencies. It can generally be stated that if an insulator is quiet in the broadcast band (550- Kc to 1550- Kc) it will cause no interference in the short wave and television bands. It is also true that if an insulator produces a certain amount of noise in the broadcast band it will be likely to produce less effect in the short wave bands.

This concept of an insulator or in fact any electrical device acting as an uncontrolled frequency converter or high frequency generator, is important to a proper understanding of the radio interference problem. This is almost exactly the function of a radio transmitter which receives energy from a power line at commercial frequency and converts it into radio frequency energy at some prescribed frequency. Associated apparatus modulates the r.f. energy produced by the transmitter and applies it to an antenna which is efficiently designed to radiate it into space.

We have developed the concept of an insulator or any interfering device as a generator of radio frequency energy over a broad band of frequencies. This radio frequency energy is fed back into the line that in turn feeds the insulator or interfering device with commercial frequency energy. Let us now look at the properties of the line or power frequency circuit as a means of communicating this energy to radio receivers. The radio transmitter is caused to feed its r.f. energy, properly modulated, into an antenna which is usually designed to radiate this energy into space as efficiently as possible. The most efficient transmitting antenna is a vertical conductor of uniform cross section. Horizontal conductors placed close to the ground are very poor radiators. For this reason transmission and distribution lines are poor radiators. The radiation of r.f. energy produced by insulators or other devices from transmission and distribution lines is therefore negligible.

The line will, however, conduct this r.f. energy along its length for several miles in either direction until it is dissipated by attenuation. It will also communicate some of this energy of other conductors and devices which are electro-magnetically or capacitatively coupled with it. Thus a radio receiver may receive this energy over the distribution circuit that feeds it through its power supply leads or by coupling between its antenna or antenna lead in wires and the power supply circuits. Auto radios pick up noise produced by line insulators or other devices on lines along the road side by direct coupling of the receiver's antenna with the lines. It is a matter of common experience that noise from a line rapidly decreases as the auto receiver moves away from the line, the noise ordinarily becoming inappreciable in 200 to 300 feet. However, a telephone line which parallels a noisy transmission or distribution line for some distance and is closely coupled with it, may carry noise from this line for several miles after the parallel construction has ceased.

The radio frequency voltage which the insulator or interfering device feeds into the line to which it is connected for a given commercial frequency line voltage depends on the impedance which the line presents to the insulator at radio frequency. If this impedance is very low the insulator is practically short circuited from a radio frequency standpoint and hence its voltage output will be low. If the impedance which the line presents is high then the r.f. voltage will be relatively high and it will be more effective in creating disturbances in nearby receivers or those coupled with the line.

The average r.f. impedance of transmission and distribution lines at points away from substations is approximately 600 ohms. The impedance presented to insulators in substations or near them is likely to be much lower than at points out on the line. This is because at substations there is usually apparatus with high electrostatic capacity to ground, such as transformers, lightning arresters, oil circuit breakers etc. High capacity elements of the system provide a low impedance for radio frequency voltages and hence act as drains to them. In effect, the noise voltages are short circuited.

Summarizing briefly radio interference may arise from any incipient or partial breakdown of the air or insulation around apparatus. In sound insulators such breakdown of the surrounding air manifests itself as visible or audible corona if located on the surface of the insulator. Hidden voids in the insulators, as in the space between the end of the pin and the bottom of a porcelain threaded pinhole in a pin type insulator may give rise to invisible and inaudible corona or discharges which may, none the less, cause interference with radio reception. The magnitude of the radio frequency noise voltages produced by insulators depends on:

1) The design and characteristics of the insulator.
2) The power frequency voltage applied across the insulator.
3) The impedance which the line connected to the insulator presents to it at radio frequencies.
4) The atmospheric conditions under which the insulator is operating.
5) The surface condition of the insulator.
6) The construction and features of the line.

The effect which this radio frequency voltage generated by the insulator produces in a radio set depends on many factors some of which are:

1) The characteristics of the receiver.
    a) Its sensitivity or response characteristic.
    b) Its selectivity or sharpness of tuning.
    c) Its design features such as automatic volume control and noise suppressors.

2) The proximity of the receiver to the noise source.
3) The effective height of the receiver's antenna.
4) The closeness of electro-magnetic or capacitative coupling between the noise source and the antenna, or power supply leads of the receiver.
5) The ratio of the intensity of the noise signal produced by the interfering source at the input of the receiver to the intensity of the desired signal (noise to signal ratio).
6) The care and thought given to the proper installation of the receiver and its antenna with reference to noise elimination.

The elimination of radio interference arising from electrical apparatus or devices is then a problem in which five parties are concerned.

1) The manufacturer of the apparatus or device.
2) The user of the apparatus or device (utility).
3) The listener or owner of the receiver.
4) The manufacturer of the receiver.
5) The radio broadcaster.

It is not probable that any one of these alone can solve the problem economically, but with the proper cooperation and coordination of all five, satisfactory results can be obtained. It may be said by some that if the manufacturers would design and build all electrical apparatus and devices so that they would produce no radio frequency voltage the entire problem would be solved and so it would if properly installed, used and maintained. However, in the present state of our understanding this is not economically possible. Much can be done and is being done by apparatus and device manufacturers to reduce the r.f. noise voltages produced by their products. The utility companies are carrying on extensive studies in the proper use and maintenance of equipment. The listeners are learning about the necessity of proper antennas and installation of receivers and about household appliances and their proper use to eliminate noise. The manufacturers of radio equipment are striving for the suppression of noise by improving the characteristics of both transmitters and receivers. The broadcasting stations are building better and more efficient antennas and increasing their output power, where permitted, to give the listener a stronger more reliable signal which cannot so easily be overridden by interfering noises.

With all this cooperative effort, with the better understanding of the problem, and with better methods for making studies, the interference problem will soon be overcome in an economical manner.

Organized Attack Upon The Radio Interference Problem

The problem of radio interference has many aspects of which the average manufacturer or user has had little conception. Radio engineering is a specialized field with a jargon and a set of concepts all its own and these are rarely understood by engineers dealing with power circuits and frequencies. Recognizing this general lack of understanding and the immense complexity of the problem a joint committee was formed in 1931 from three organizations vitally interested. These organizations are,

1) The National Electrical Manufacturer's Association.
2) The Edison Electric Institute.
3) The Radio Manufacturer's Association,

and the committee is known as "The Joint Coordination Committee on Radio Reception". Progress has necessarily been slow but gradually order and principles have been evolved out of a generally chaotic condition.

One of the most important tasks involved was to establish a reliable and standard technique for measuring the radio noise characteristics of various classes of electrical devices. For instance practically all insulator manufacturers have made so called radio interference tests on various types of insulators for the past 12 to 15 years, but a survey made under the auspieces of NEMA in 1936 and 1937 showed that no two manufacturers were using methods or equipment which were even remotely similar. It was therefore hardly to be expected that comparable results could be obtained. Furthermore there was need for a quantitative measure for determining how much radio noise was being produced in a given case, but no universally recognized quantitative unit for radio noise was available. Accordingly a Subcommittee was formed of individuals well qualified in this field from the three organizations mentioned to study and develop instruments and methods of measurement. This subcommittee was known as "The Subcommittee on Instruments and Methods of Measurement". It studied the problem exhaustively, and in December 1935 published a report entitled "Methods of Measuring Radio Noise". This report was adopted by the three sponsoring organizations and published by each of them as standards. (EEI Publication G-9, NEMA Publication No. 102, and RMA Engineering Bulletin No. 13). In the ensuing four years the recommendations set forth in these publications have gradually but surely received general recognition. Adoption generally by manufacturers and users has been slow because it has required much education and much discussion to bring executives and engineers unfamiliar with radio concepts to an appreciation of the fundamentals involved and the need for improvement of products from this standpoint.

During this period some experience has been gained in the use of the methods of measurement which had been developed and because of this experience it was to be expected that improved methods would be found. During 1939 the original report was redrafted with many improvements and refinements in the equipment recommended and the methods suggested. This revised report, known as NEMA Publication No. 107, is now available in printed form. This was also adopted by EEI and RMA and is known as EEI Publication G-9 and RMA Engineering Bulletin No. 32.

The Fundamental Basis of Radio Noise Measurements.

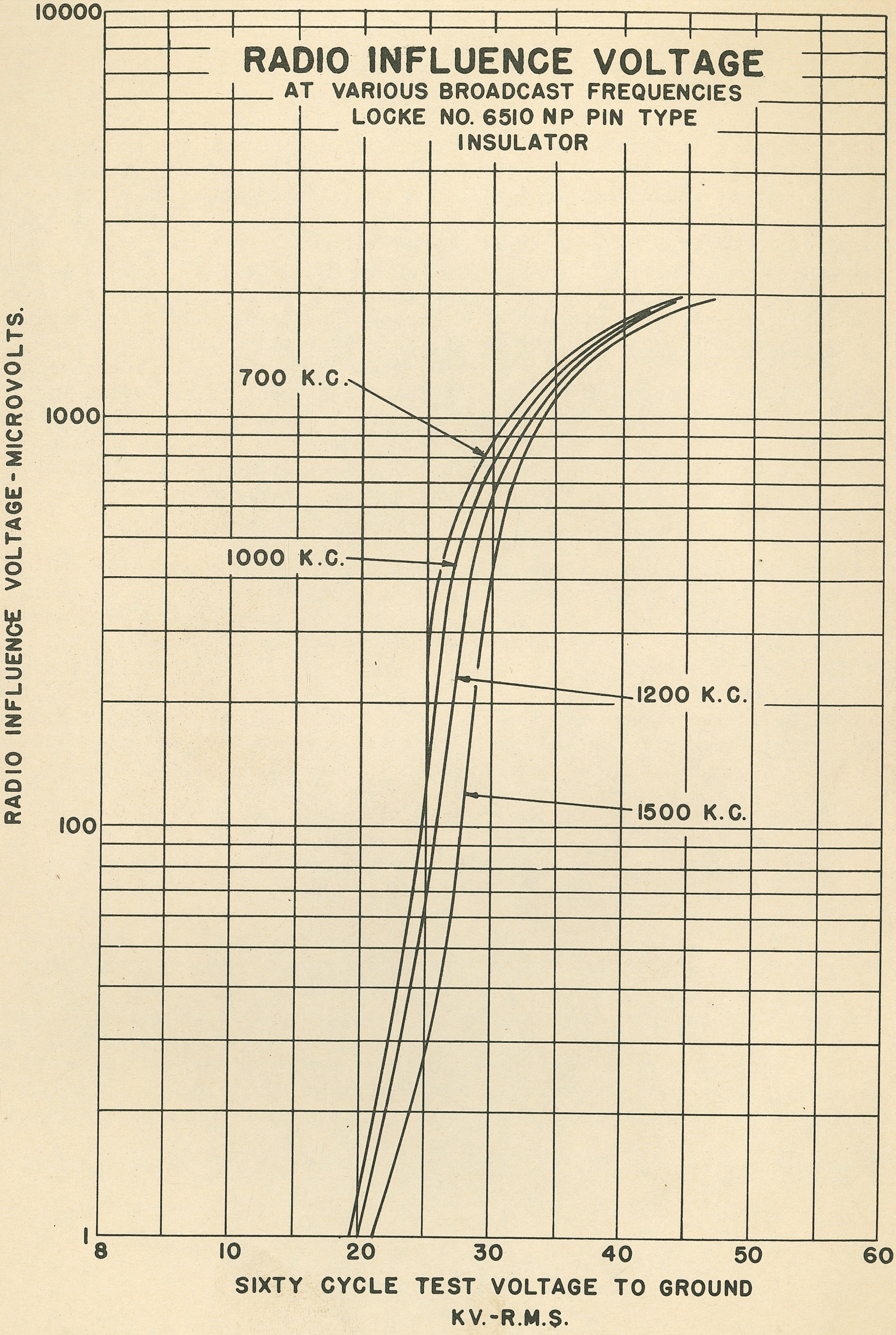
After studying the problem, the Subcommittee on Instruments and Methods of Measurement decided that the radio interference producing capabilities of all devices could best be determined by measuring the crest value of the radio frequency noise voltage generated by them. This radio frequency voltage is measured by energizing the device under test to the desired voltage at commercial frequency in a special test circuit. This test circuit is arranged to present an impedance of 600 ohms to the device at the radio frequency at which the measurement is being made. The radio frequency voltage generated by the device under these conditions is measured through a suitable network by means of a radio frequency voltmeter called a "Radio Noise Meter". This instrument is a special type of radio receiver having standardized characteristics and containing a calibration source and an indicating output meter. The crest value of the radio frequency voltage so measured is called the "Radio Influence Voltage". This voltage is usually of very small amplitude and is conveniently measured in microvolts (millionths of a volt).

This voltage should not be confused with the Field Strength produced by the device under test. Field strength is the voltage induced in an antenna having an effective height of one meter located at the point where the field strength is to be explored. Field strength is measured in Microvolts per meter and depends upon many things such as the distance of the antenna from the source, the radiating properties of the circuits connected to the source and the electro-magnetic and capacitative coupling between them and the antenna. Field strength may be measured by a suitable Radio Noise Meter connected to an antenna which has a known effective height. In such a measurement the field strength is the voltage measured by the Radio Noise Meter divided by the effective height of the antenna. Measurements have shown that the Field Strength produced at 10 feet from a conductor supported by an insulator producing a Radio Influence Voltage of 100 microvolts is only about 1.2 microvolts per meter.

The complete Radio Influence Characteristics of an insulator or electrical device may be shown by a family of curves in which the Radio Influence Voltage is plotted against the sixty cycle voltage applied across the insulator or device. Similar curves may be made for several different radio frequencies. Figure 1 shows a typical set of curves for a Locke No. 6510-NP insulator. This gives the complete characteristics for this insulator in the broadcast band, 550 to 1550 KC. Standard tests are always made at 1000 KC.

Description of the Testing Circuit and Equipment for High Voltage Apparatus.

Several types of filter networks are required for measuring the Radio Influence characteristics of different classes of apparatus. We will discuss here only the circuit used for high voltage apparatus such as insulators, bushings, fuse cut outs, disconnect switches, lightning arresters, etc.



RADIO INFLUENCE VOLTAGE
AT VARIOUS BROADCAST FREQUENCIES
LOCKE NO. 6510 NP PIN TYPE
INSULATOR

The nature of the circuit must be such that the apparatus or insulator under test can be energized in the same manner as when in service to some voltage above the maximum voltage at which it may be used. For instance a Locke No. 1044-NP is usually used on a 33- kv circuit. The maximum operating voltage of such a circuit does not usually exceed 34.5-kv line to line. The maximum line to ground voltage is then 34.5 divided by 1.73 or 20- kv. We therefore would wish to be able to test this type of unit up to some arbitrary percentage above this normal voltage to ground. In order to make the measurement the insulator or device must be energized to its maximum service operating voltage so that it may exhibit its radio frequency generating capabilities. While so energized with 60 cycle voltage we must measure the radio frequency voltage which it generates. If we connect a sensitive voltmeter capable of measuring these feeble r.f. voltages directly across the test specimen it would be damaged by the high sixty cycle voltage. So we must use a filter network which will offer a low impedance to radio frequency voltages and almost infinite impedance to 60 cycle voltage. Since an insulator sees an impedance of 600 ohms at radio frequency on the average line, this impedance is used in the network. The noise meter is connected across a portion of this 600 ohms impedance and measures the r.f. voltage generated by the insulator, while the high 60 cycle voltage applied to the test specimen is blocked from the noise meter by the filter network. (Figure 2 shows the standard network recommended by the Subcommittee on Instruments and Methods of Measurements).

The insulator "D" to be tested is energized by the high voltage testing transformer "T" to the desired voltage through the r.f. choke "L" which has an impedance of 20,000 ohms or more at all radio frequencies but negligible impedance at 60 cycles. We will assume that the particular insulator being tested develops corona at the test voltage applied. It therefore generates radio frequency voltage and feeds it back into the test bus which supplies the 60 cycle voltage. Since the r.f. choke "L" has high impedance at radio frequency it prevents the r.f. voltage generated by "D" from going back to the high voltage winding of the supply transformer and so prevents it from being drained off through the capacity of the bushing on the transformer and the capacity of the end turns of the high voltage winding to the core, the tank and low voltage winding of the transformer.

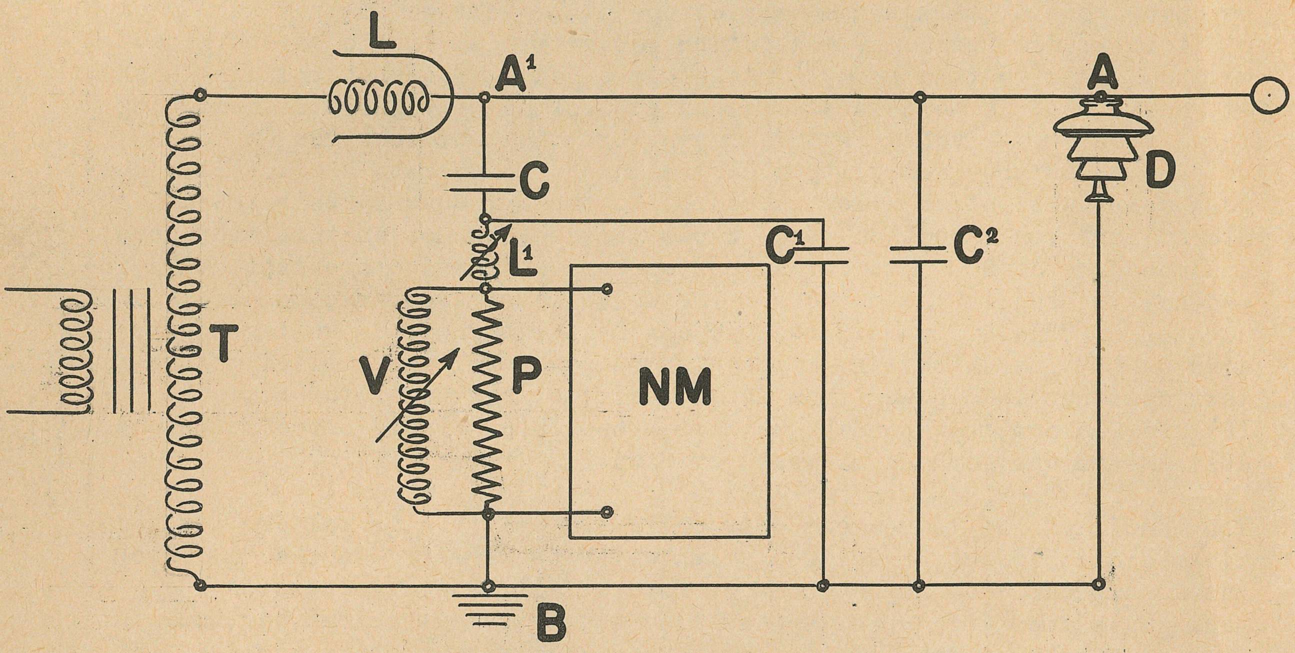
The r.f. voltage generated by "D" therefore is impressed across the measuring branch of the circuit A^1B. The high voltage condenser "C" and inductor L_1 present only their effective resistance to this r.f. voltage since they have been turned to resonance at the frequency at which the measurement is being made. If it were possible to have a perfect condenser and inductance respectively, there would be no resistance, but since "C" has organic insulation and metallic plates it produces a small resistance component. Likewise L_1 being a practical coil presents some resistance. However, at sixty cycles they present almost infinite impedance and thus block the 60 cycle test voltage from the potentiometer "P" and the noise meter.

Circuit Diagram of the Locke
Radio Influence Voltage Testing Set

Figure 2.

T - High Voltage Testing Transformer

L - Radio Frequency Choke Coil Shielded, having an impedance of not less than 20,000 ohms at the frequency at which the measurement is made.



N.M.- Radio Noise Meter.

C - High Voltage Radio Frequency Coupling Condenser not less than 2500 micro micro farads capacity.

D - Insulator or device under test.

P - Non-inductive resistor approximately 600 ohms.

L_1 - Tuning coil to tune condenser C to approximately resonance at frequency of measurement.

C_1 - Stray capacitance of leads and condenser C on noise water side of C.

C_2 - Stray capacitance of test lead on device side of C.

V - Variable inductance to tune out effect of stray capacity C_1 and C_2 to maintain 600 ohms impedance between points A & B at all frequencies of measurement.

Thus the radio frequency voltage generated by "D" is impressed across the effective resistance of "C" and "L_1" in series with the non-inductive resistance "P" but is blocked from feeding back through the test bus to the transformer by the r.f. choke L. In advance of the test the resistance of "C", "L" and "P" in series has been adjusted to within 1% of 600 ohms, so that this is the only impedance seen by the test piece except for the stray capacity to ground of the test bus between "A^1" and "A" (indicated as "C_2" on the diagram) and the stray capacity of "C" and the connecting leads to ground (indicated as C_1). These are tuned to parallel resonance by the variometer "V" leaving in only the 600 ohms impedance. The noise meter is connected across "P" and its reading must be multiplied by the ratio of 600 to the resistance of "P" to obtain the correct value.

The noise meter is in effect a special type of superheterodyne radio receiver with a standardized sensitivity and selectivity, thus it acts as a very sensitive radio frequency voltmeter and indicates on an output meter the crest value of the radio frequency voltage impressed across "P" at the frequency to which it (the noise meter) is tuned. The noise meter may be tuned to any desired frequency in the broadcast band and when "V" and "L_1" are properly adjusted for this frequency the noise meter reads in proportion to the r.f. voltage which the insulator produces at that frequency due to the sixty cycle voltage applied to it. Thus the insulator "D" may be tested under controlled conditions and its radio noise voltage output (Radio Influence Voltage) measured at any desired frequency in the broadcast band, for any value of applied sixty cycle voltage.

Description of the New Radio Interference Measuring Equipment Installed in the Locke High Voltage Laboratory

The Locke Insulator Corporation is equipped with a high voltage radio interference testing set of the most modern type fully complying with the latest provisions of the Joint Coordination Committee on Radio Reception. It fully complies with recommendations of the new NEMA Publication No. 107. This equipment is for use in conjunction with the 60 cycle High Voltage Testing Set located in the High Voltage Laboratory. The high voltage condenser "C" is rated for a maximum r.m.s. sixty cycle test voltage of 130- kv continuously. This equipment consists of the following items:

1) A 130- kv Pyranol Filled Radio Frequency Coupling Condenser of special construction best suited for this type of work.
2) A net work cabinet containing inductor L_1, inductor V, non-inductive resistor "P" and safety devices for the operator's protection.
3) A Ferris Model 32-A Radio Noise Meter and Field Intensity Meter complete with battery and power packs for "A" and "B" power supplies, internal calibrator, 1/2 meter antenna, etc. This noise meter reads Radio Noise Voltage directly from 10 to 100,000 microvolts.

4) A portable control room complete with safety circuits where the operator may control and observe the sixty cycle voltage applied to the test specimen and at the same time operate the noise meter and associated equipment.

5) A Model 160 RCA Cathode Ray Oscilloscope for observing the audio output of the noise meter with reference to the sixty cycle voltage applied to the test specimen.

6) Approximately 75 feet of high voltage noise free bus with accessories for making high voltage corona free connections to the devices under test.

7) Suitable remote control equipment whereby the operator may control the output of the sixty cycle testing transformer at will from the control room.

A general view of this equipment is shown in Figure 3, while Figure 4 is a photograph of the high voltage coupling condenser "C" and r.f. choke "L". The r.f. choke "L" is shielded in the corona shield at the upper end of the condenser housing. Figure 5 shows a close up view of the radio noise meter. The various items are identified on these photographs.

Standard Specifications for the Radio Influence Voltage Performance of High Voltage Insulators.

Now that standard, nationally accepted instruments and methods have been established on a sound basis to measure the Radio Influence Voltage produced by various types of electrical apparatus and devices and since a mass of data has been taken on their performance under such a test, we should be able to begin to establish standards of acceptable performance for various types of apparatus. This is the phase we are now entering and tentative standards are being established on a wide variety of equipment. For the most part this is being done cooperatively by the various branches of the industry, wherein certain classes of equipment are being studied jointly by the manufacturers of these classes and standards set accordingly.

Such standards involve many considerations some of which are,

1) The microvolt level which is required to avoid interference with radio reception.

This requirement varies with the area in which the device is to operate and with the type of circuit with which it will be associated. It must continually be kept in mind that radio interference is a relative matter. So long as the ratio of the microvolt input of the desired signal to the radio receiver from its antenna is approximately 32 or more times that of the unwanted noise voltage the reception will be perfect and unmarred by the noise. As this ratio of signal strength to noise strength falls reception will become more and more unsatisfactory until finally the desired

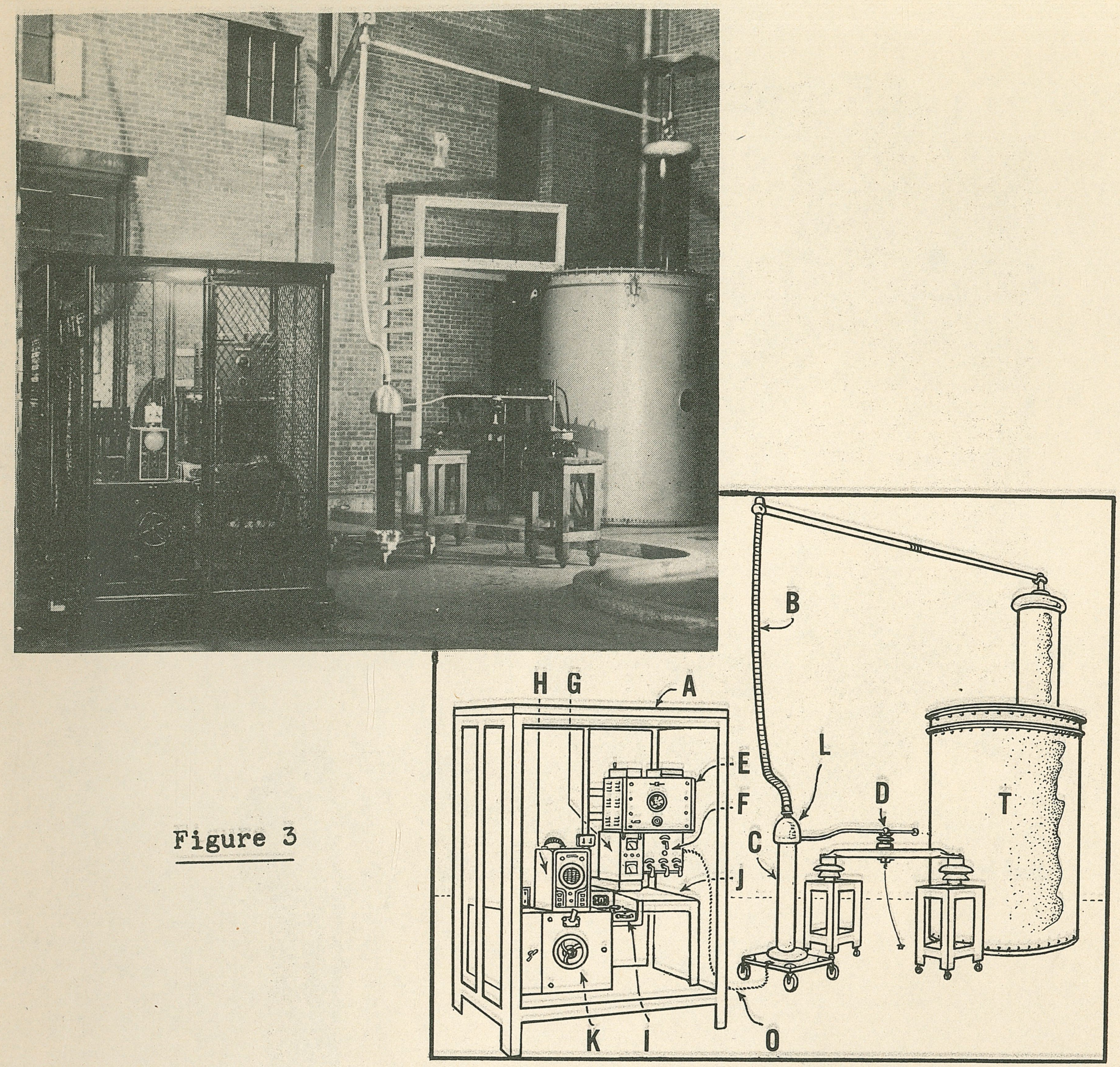


Figure 3

A. PORTABLE CONTROL ROOM.

B. HIGH-VOLTAGE CORONA-PROOF BUS.

C. COUPLING CAPACITOR.

D. INSULATOR UNDER TEST.

E. COMPENSATING CIRCUIT CABINET.

F. MINATURE CONTROL BOARD FOR CONTROLLING HIGH-VOLTAGE TEST SET.

G. RADIO NOISE METER.

H. CATHODE-RAY OSCILLOGRAPH.

I. VOLTMETER TO INDICATE VOLTAGE ON TEST PIECE.

J. OPERATOR'S DESK.

K. VOLTAGE CONTROL RHEOSTAT.

L. SHIELDED RADIO FREQUENCY CHOKE.

O. CONCENTRIC SHIELDED LINE CONNECTING CAPACITOR TO COMPENSATING CIRCUIT.

T. HIGH-VOLTAGE TRANSFORMER.

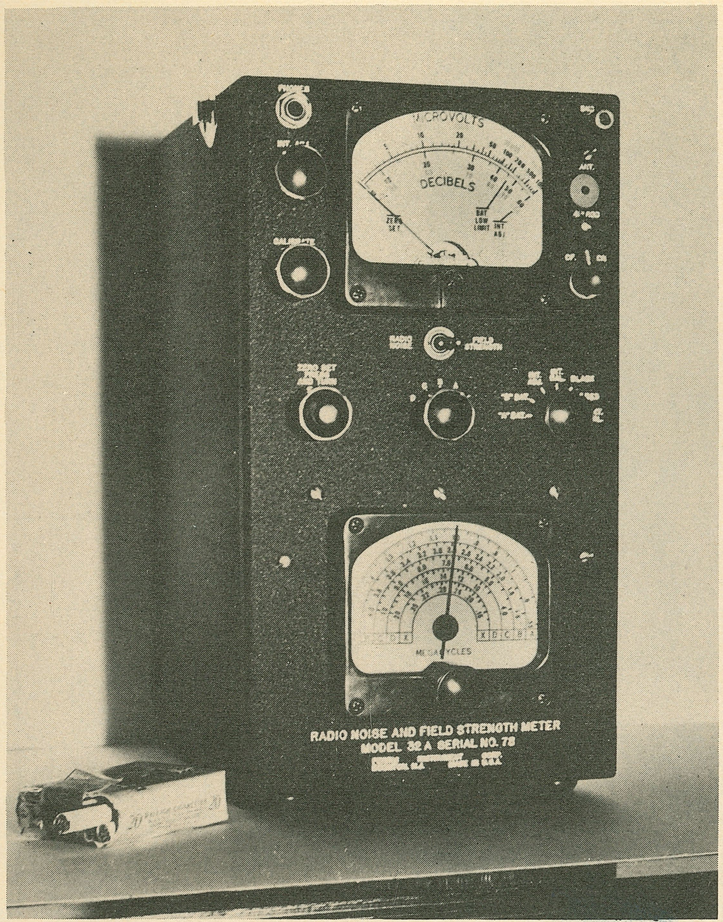


Figure 5

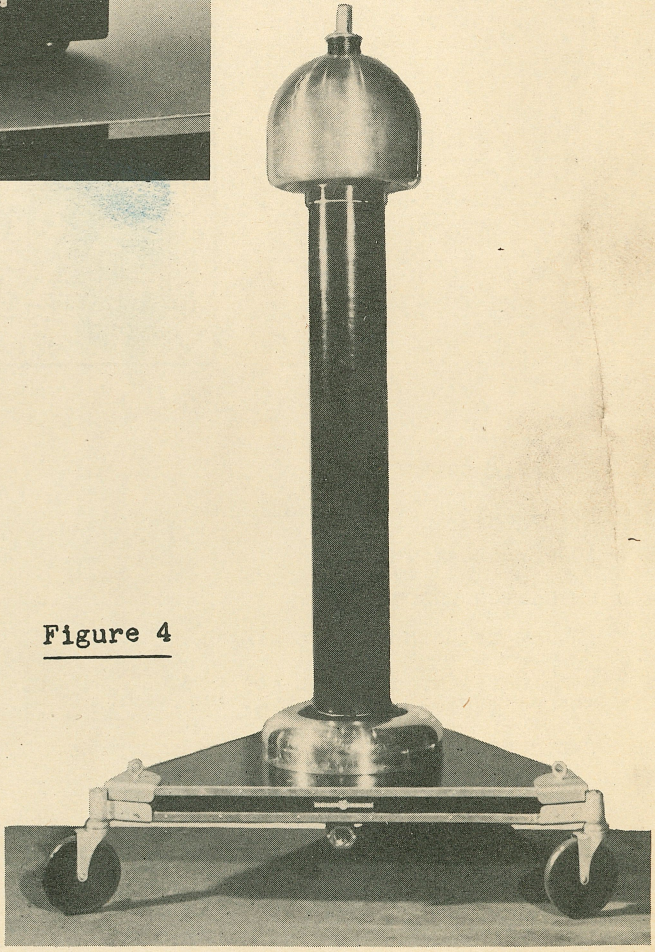


Figure 4

signal will become unintelligible and the noise will predominate. This ratio of 32 to 1 holds for noises of nearly continuous character. For intermittent noises of certain types a somewhat lower ratio can be tolerated. It is for this reason that plain, untreated pin type insulators, which produce relatively high Radio Influence Voltages at their usual operating voltages have caused little or no trouble in urban areas well served by broadcasting facilities, and yet similar insulators have been a constant source of annoyance to listeners in rural districts outside the primary coverage areas of the broadcasting stations.

2) The voltage of the circuit with which the device will be associated.

Distribution circuits of necessity come into close proximity and are intimately coupled with every radio receiver operated from electric supply lines. Insulators and other devices on distribution lines must therefore be relatively more quiet than those on medium voltage lines which do not go down every street and alley. Moderate voltage lines, however, often run along important thoroughfares and are sometimes closely coupled with receivers, for this reason their noise levels must be kept low. High voltage lines usually avoid populous districts and are remotely coupled with receivers through several stepdown transformers, and so for them a higher noise level may be tolerated.

3) The level which can be economically attained in the present state of our understanding of methods for suppressing noise on the insulator or device in question.

Certain types of insulators such as suspensions are inherently relatively quiet and seldom need improvement in their noise influence characteristics. On the other hand conventional pin type insulators are inherently noisy but yield with simple modification to very satisfactory improvement. Most switch and bus insulators are reasonably quiet but at the higher voltages they need special attention. Many type of solid bushings require somewhat expensive treatment to make them satisfactorily quiet. No doubt as time goes on and a better understanding of the principles is attained better methods will be developed which will permit even greater improvements at less cost.

There has long been a need for a uniform standard of acceptability for so called radio free apparatus, particularly radio free insulators, but as long as there was no uniform standard method of measuring the radio noise capabilities of various devices nor a uniform terminology, such a standard was impossible. Now, however, we have the tools and the terminology. In the past almost all manufacturers of insulators have attempted to express the radio noise performance of insulators as the limiting commercial frequency voltage which could be applied to them at which radio noise could just begin to be detected. This involved the question of when radio noise started which in turn depended on the sensitivity of the pick-up circuit and radio receiver used. Under these conditions wide variations in test results were obtained. Now we have a standard pick-up circuit which any-one can duplicate and a standard receiver (noise meter) with standard performance and sensitivity. Further, we recognize no such thing as "no radio noise", but rather set limits of acceptability. Experience with the present testing circuits has shown that measurements below 10 microvolts Radio Influence Voltage cannot be made accurately since there is no method of eliminating extraneous noises at this level.

The High Voltage Insulator Section of NEMA through the cooperation of its members has to date investigated the Radio Influence Voltage characteristics of Plain Pin Type Insulators, Radio Freed Pin Type Insulators and Switch and Bus Insulators. From the data so collected performance test standards have been established, based on the performance of insulators of a quality generally available in the industry. In both the Pin Type and the Switch and Bus Type Insulator the limiting values for radio free units have been set low enough so that under rather extreme low strength conditions of the desired signal, interference should not be experienced. These standards comprehend a maximum operating voltage across the insulator in service, a test voltage of 10% higher than the maximum operating voltage and a limiting Radio Influence Voltage for acceptability when this test voltage is applied. In the case of Pin Type insulators the insulators have been classified according to their rated 60 cycle dry flashover voltages since there are no well recognized rated operating voltages. For easy reference in the tabulations for radio freed pin type units a recommended maximum operating voltage has been included. The corresponding line to ground voltages for these maximum recommended operating voltages is about 10% below the test voltages given.

Standard For Radio Freed Pin Type Insulators

Pin Type Insulators Having Rated Dry Flashover Values in this range - KV	When Tested At the Following RMS Voltage to Ground - KV	Shall Produce Not More Than The Following Radio Influence Voltage (Microvolts) at 1000 KC
Up to and Including 50	6	50
51 - 79	10	50
80 - 109	15	100
110 - 124	22	100
125 - 149	30	200
150 - 200	44	200

Example.

In order to illustrate the use of this Standard the following example is given.

> It is desired to improve a 33- kv line from the radio interference standpoint by reinsulating the line with Locke NP insulators. What insulator should be selected. The maximum line to line voltage of a

nominally rated 33-Kv circuit will not exceed 34.5-Kv. This corresponds to 19.9-Kv line to ground. In the third column of the table above we find a test voltage of 22-Kv which is more than 10% above this line to ground voltage. This test voltage corresponds to a maximum recommended operating voltage of 34.5 and so the insulator selected should have a 60 cycle dry flashover rating of 125-Kv to 139-Kv. From the Locke catalog, Locke No. 1044-NP has a 60 cycle dry flashover rating of 125-Kv and therefore meets the requirements. Unless atmospheric conditions are particularly severe or it is desired for some reason to overinsulate this line Locke No. 1044-NP should be selected. Specifications should call for units selected at random from the lots furnished to be tested at 22-Kv to ground at which voltage the Radio Influence Voltage when measured in accordance with EEI Specification G-9, NEMA Publication No. 107 should not exceed 100 microvolts. If for other reasons larger units are desired they may be used and the Radio Influence Voltage on larger units will be lower at this same test voltage. If the customer prefers the insert type of unit to the Metaglaze treated type or the post type, then No. 23524 or No. 23603/23613 should be selected for those conditions.

Standards of Performance for Untreated Conventional Pin Type Units

In many areas well served by broadcasting stations plain pin type insulators may be used satisfactorily and a table of standard performance values has been prepared for these. Since such units are in no sense to be considered as radio freed units, these values should not be looked upon as limits of acceptability, but as useful information for comparison purposes. They give the user an idea of untreated insulator's performance under a similar test devised for determining the performance of radio free units. Therefore, please note that where the last column of the preceding table states, "Shall produce not more than the following microvolts R.I.V.", the last column in the following table states, "Will produce not more than the following microvolts R.I.V."

Standards for Plain Pin Type Insulators.

Pin Type Insulators Having Rated Dry Flashover Values in this Range - KV	When Tested at the Following RMS Voltage to Ground - KV	Will Produce Not More Than The Following Radio Influence Voltage (Microvolts) at 1000 KC
Up to and Including 50	5	2500
51 to 79	10	5500
80 to 109	15	8000
110 to 124	22	12000
125 to 149	30	16000
150 to 200	44	25000

The surface so treated has an attractive appearance which blends with mahogany and chocolate glazes without appreciable contrast, yet it is obvious on close inspection that the unit is of the treated type thus making treated units readily detectable. When used with white glaze, a marked contrast will result between the treated and untreated areas and it is impossible to avoid some discoloration of the white glaze in an area not over 1/2" wide adjacent to the treatment.

Where the Treatment Will be Applied

The areas to be treated will depend on the design of the insulator and its operating voltage. One piece distribution units are glazed with Metaglaze on the head to a point slightly beyond the side wire grooves and in the pinholes where the threads are formed in the porcelain. Multipart and one piece high voltage pin type units up to and including No. 1044 and No. 1244 will be treated on the head only, extending out on to the top of the shell slightly beyond the head diameter. Pin holes and joints will not be treated but metal threaded pinholes or cemented in thimbles will be furnished. Larger high voltage pin types will be treated on the head as shown and probably at each joint on all shells. Metal threaded pin holes or cemented in thimbles will be furnished and a small area at the opening of the pinhole will be treated. One piece units and multipart units which ordinarily have a firing foot on top of the head will continue to be unglazed in this area, for this purpose. This will in no way effect the performance or permanence of the unit from any standpoint and it will avoid unsightly unglazed areas on the under side of the units.

Treated Switch and Bus units will be treated in the area surrounding the cap, the treatment extending from the Locketite compression grips bending the cap out for an inch or more beyond the edge of the cap. Treatment will probably be applied in bands at each joint and in a small area around the pin. Exact diameters will not now be specified for commercial purposes until further experience with the optimum diameters has been obtained.

Weatherproof Conductor

Many operating companies prefer to use triple braid weatherproof wire for urban distribution lines. Such wire, when new, may improve the Radio Noise performances of the lines, but the insulating value of such weatherproofing material rapidly deteriorates and since such weatherproofing is highly stressed electrically where it contacts the supporting insulators it will break down soon resulting in a continuous charging current arc through the broken down weatherproofing. Such arcs will produce violent radio interference. Therefore, where weatherproof wire is used, the weatherproofing should be stripped clean from the conductor at the point where it is tied to the insulator and the tie should be made with a bare copper tie wire when a copper conductor is used or with a bare aluminum tie wire where an aluminum conductor is used, so that good contact will be made directly between the Metaglaze coating and the conductor and tie wire.

Finally, a word of caution. Insulators are not the only source of radio interference on transmission lines. Radio free insulators can only eliminate that interference arising from the insulators themselves. Care should be taken in making ties so as not to leave sharp ends projecting out from the conductor. Either the ends should be terminated in loops bent in close to the conductor for hot line work or the sharp ends should be hammered down close to the conductor. All hardware on the structures should be kept tight and all unbonded metal pieces should be kept well separated from each other. Floating pieces of hardware in close proximity to other floating, live, or grounded parts, may promote corona and static sparks which will cause very annoying and vociferous interference. Last, but not least, other apparatus such as fuse cutouts, lightning arresters, transformers, transformer bushings, protective gaps, disconnect switches and so forth, not in themselves radio free, may nullify all of the improvement obtained by the use of radio free insulators. To make a line truly noiseless all of its individual parts and the apparatus connected to it must be noiseless. Even with all this accomplished, power and domestic customers' equipment, if noisy, may feed noise voltage back into the line, and it becomes necessary to remedy these conditions also if the desired result is to be obtained.

SUSPENSION INSULATORS

The following are tentative standards for the Radio
Influence Voltage Performance for Radio Freed
Suspension Insulators

- o O o -

Radio Influence Voltage Data for Radio Freed
9 to 12" Diameter Cap and Pin Type Suspension
Insulators With Corrugated Shells, Ball and
Socket or Clevis Connection for all M.& E. and
Ultimate Strength Ratings up to and Including
15,000 Pounds, in Spacings from 4-3/4 to
6-1/2"

Radio Freed Suspension Insulator Strings for the class included in the foregoing when tested in strings of the number of units shown in column 1, with the sixty cycle test voltage corresponding given in column 2, shall not produce radio influence voltages in excess of those given respectively in column 3.

Column 1	Column 2	Column 3
No of Units in String	Test Voltage to Ground, KV - rms.	Maximum Radio Influence Voltage in Microvolts at 1000 KC
1	10	50
2	25	100
3	40	200
4	50	200
5	60	200
6	70	200
7	80	500
8	85	500
9	90	500
10	95	500

The above values apply when equipment and methods are used which are in accordance with the recommendations of the Joint Coordination Committee on Radio Reception as set forth in EEI Publication G-9, NEMA Publication No. 107, RMA Engineering Bulletin No. 32, and AIEE Standards No. 41

Radio Influence Voltage Data for Radio Freed 6" and 7-1/2" Diameter Cap and Pin Type Suspension Insulators with Corrugated Shells, Ball and Socket or Clevis Connection for all M.& E. and Ultimate Strength Ratings up to and including 15,000 Pounds in Spacings from 4-3/4 to 6-1/2".

- o O o -

Radio Freed Suspension Insulator Strings of the class included in the foregoing when tested in strings of the number of units shown in column 1, with the sixty cycle test voltage corresponding given in column 2, shall not produce radio influence voltages in excess of those given respectively in column 3.

Column 1 No. of Units in String	Column 2 Test Voltage to Ground, KV - rms	Column 3 Maximum Radio Influence Voltage in Microvolts at 1000 KC
1	7.5	50
2	10	50
3	15	100

The above values apply when equipment and methods are used which are in accordance with the recommendations of the Joint Coordination Committee on Radio Reception as set forth in EEI Publication G-9, NEMA Publication No. 107, RMA Engineering Bulletin No. 32, and AIEE Standards No. 41.

METHODS OF MEASURING RADIO NOISE

1940

A Report of the Joint Coordination Committee on Radio Reception of E.E.I., NEMA and R.M.A.

SUMMARY

This report contains the recommendations of the Joint Coordination Committee on Radio Reception of E.E.I., NEMA and R.M.A., as to the nature, essential characteristics and performance of a meter for the measurement of radio noise. It further gives detailed descriptions of recommended practices in the use of the meter for measuring directly radio noise from low and high voltage apparatus, for making radio noise measurements along overhead lines, for determining broadcast field strengths, and for collecting data for the establishment of radio noise standards.

E.E.I. Publication No. G9
NEMA Publication No. 107
R.M.A. Engineering Bulletin No. 32
Published February, 1940

Price 20¢ to members and their employees
Price 50¢ to non-members in U.S.A.
Price 60¢ to foreign countries

These prices include mailing charges

EDISON ELECTRIC INSTITUTE
420 Lexington Ave., New York, N. Y.

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION
155 East 44th Street, New York, N. Y.

RADIO MANUFACTURERS ASSOCIATION
1317 F Street, N. W., Washington, D. C.

CONTENTS

PAGE

Introduction.......... 1

Specifications for a 150 to 18,000 kc Radio Noise Meter.......... 1

Methods for the Measurement of Radio Noise-Influence Voltage.......... 3

Method for the Measurement of Radio Noise Voltage in the Field.......... 6

Methods for the Measurement of Radio Noise Field Intensities.......... 6

Measurements at a Radio Receiving Location.......... 7

Submission of Data.......... 7

Suggested Forms for Data Sheets.......... 9

Printed in the United States of America
Mack Printing Company, Easton, Pa.

METHODS OF MEASURING RADIO NOISE

I—Introduction

The term radio noise as used in this report refers to any electrical disturbance which excites or is capable of exciting a radio receiver in such a way as to produce acoustic noise. In order that the characteristics of apparatus producing these effects may be treated and classified in precise terms and in order that the most satisfactory method of radio noise suppression may be employed in a given case, it is necessary that there be available some method of measuring radio noise voltages which is significant in relation to radio reception. It is also desirable that there should be national understanding and agreement as to the method of measurement.

The radio noise voltage produced by electrical apparatus depends upon the high-frequency voltage generated, the internal impedance of the apparatus, and the character and impedance of the load. This voltage is propagated by conduction, induction, radiation, or a combination of these. All metallic materials, whether used normally for electrical systems or for other purposes, may conduct high-frequency energy. The radio noise effect of electrical apparatus on a receiver antenna is influenced by most of the above factors in addition to coupling and susceptiveness.

The general problem of radio noise is being actively studied through the cooperative efforts of the Edison Electric Institute, National Electrical Manufacturers Association, and Radio Manufacturers Association. In 1932 the Joint Coordination Committee on Radio Reception of these associations adopted specifications for a Radio Noise Meter and Methods of Measurement. These specifications were published in N.E.L.A. Publication No. 32 in 1933 and were revised and published in E.E.I. Publication C9, N.E.M.A. Publication 102 and R.M.A. Engineering Bulletin No. 13 in 1935. Due to advances in the radio art and increased use of the radio frequency spectrum, it has been necessary to extend and revise these specifications.*†

In presenting these specifications, the Committee wishes to point out that it has not intended to specify construction details of apparatus or methods except in so far as appears essential in order to secure reliable and comparable data from various sources.

II—Specifications for a 150 to 18,000 Kc Radio Noise Meter

The following specifications define the characteristics and performance of a noise meter for the measurement of radio noise.

General

The primary standard of calibration shall be the rms voltage of an unmodulated sine wave signal, such as that which is generated by a standard signal generator. The included signal source may be a secondary or transfer standard and shall provide for calibration in terms of the primary standard.

The calibration for the measurement of the field intensities in rms microvolts per meter shall be obtained from the voltage calibration and the values of the effective height of the antenna in meters supplied with the instrument.

For purposes of measurement at frequencies up to 1,600 kilocycles, the vertical component of the field shall be considered. (For higher frequencies the maximum value determined by tilting the rod antenna may have to be considered.)

A suitable signal source shall be included which can be used for standardizing the gain of the meter.

Sensitivity

The sensitivity shall be such that it will not be necessary to read the included indicating instrument at less than 10 percent of full angular deflection.

Meters intended for field use should have a sensitivity and range to permit measurements of input voltages from 10 microvolts to 100 millivolts, and field intensities from 10 microvolts per meter to 100 millivolts per meter.

Attenuator

An attenuator shall be provided between the input circuit and the amplifying circuit.

It is recommended that the attenuator steps correspond to ratios of 1, 10 and 100.

Linearity

Sufficient range of linearity shall be provided so that negligible wave distortion will occur within the meter on the application of a range of sinusoidal input voltage up to peak values of 100 times the full scale value of the indicating instrument.

Frequency Range

The frequency range of the noise meter shall be at least 150 to 350 and 540 to 18,000 kilocycles.

Selectivity

The selectivity of the receiver circuits shall fall within the following limits:

0 to 2 kc off frequency between +1.5 db and −1.5 db
2 to 4 kc off frequency between +1.5 db and −6 db
4 to 5 kc off frequency between +1.5 db and minus infinity
5 to 10 kc off frequency below 6 db
Beyond 10 kc off frequency below 20 db

The image response ratio shall be at least 30 up to 1,600 kilocycles, and at least 5 up to 18,000 kilocycles. The intermediate frequency rejection ratio shall be at least 50 at any frequency above 540 kc and at least 15 below 350 kc. Measurement of ratios and selectivity shall be made in accordance with I.R.E. standards.

Shielding

The shielding of the receiver circuits shall be such that when the receiver is tuned to a signal of any frequency of any intensity within its normal range, and the antenna is then withdrawn, the indication of the indicating instrument shall decrease by a factor of at least 1,000.

Antenna

The noise meter shall have a collapsible vertical rod antenna.

It is recommended that the antenna not exceed seven feet in length.

Input Circuit

The meter input circuit shall be suitable either for use with the standard antenna described in the preceding section, or with suitable coupling circuits as shown by Figs. 1 to 4 and 6 to 7, inclusive. It must at all times be properly aligned.

The meter input shall have an impedance of not less than 5,000 ohms at any frequency lower than 1,600 kc.

---

* See A.I.E.E. Paper No. 39-144, Instruments and Methods of Measuring Radio Noise, by C. V. Aggers, D. E. Foster and C. S. Young.

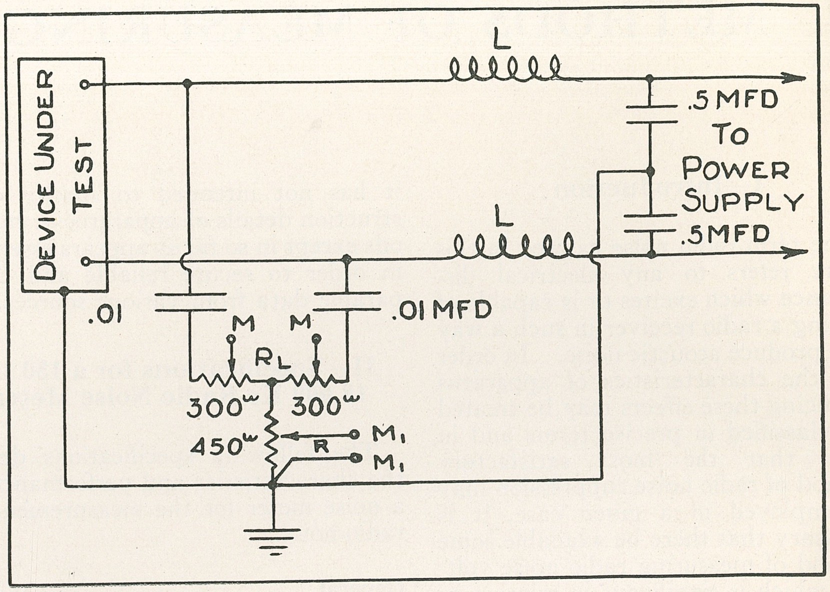
† Similar work has been carried on in Europe by the International Special Committee on Radio Interference (C.I.S.P.R.) of the International Electrotechnical Commission, and in Canada by the Dominion Department of Transport.

Fig. 1—Circuit for the Measurement of Radio Noise-Influence Voltage of Single-Phase Low Voltage Devices

M-M —Terminals for Line-to-Line Measurements

M_1-M_1—Terminals for Line-to-Ground Measurements

L —Radio Frequency Choke Coils



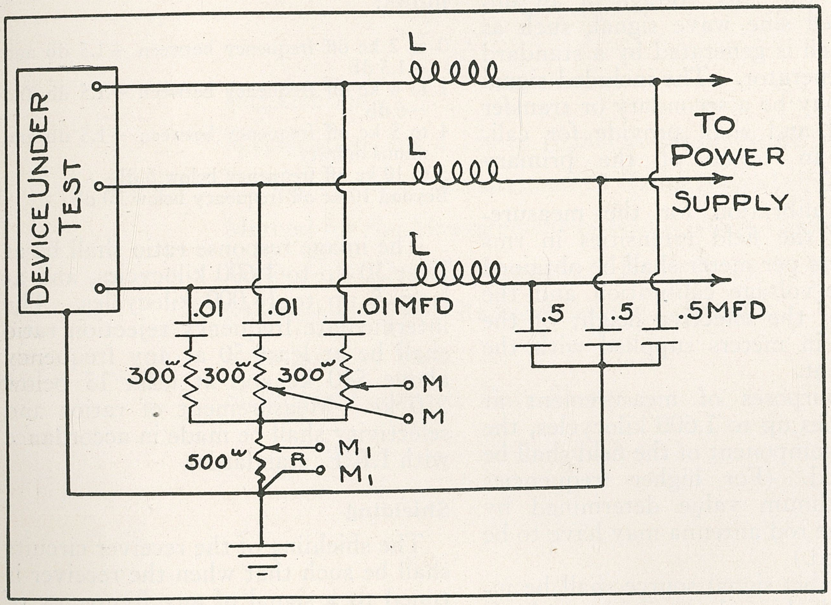


Fig. 2—Circuit for the Measurement of Noise-Influence Voltage of Three-Phase Low Voltage Devices

Fig. 3—Circuit for the Measurement of of the Noise-Influence Voltage of High Voltage Devices

T—Testing Transformer

L—R.F. Choke, Not Less Than 20,000 Ohms at Radio Frequency at Which Measurement is Made

M—Radio Noise Meter

C—Coupling Capacitor, Not Less Than 0.0025 mf.

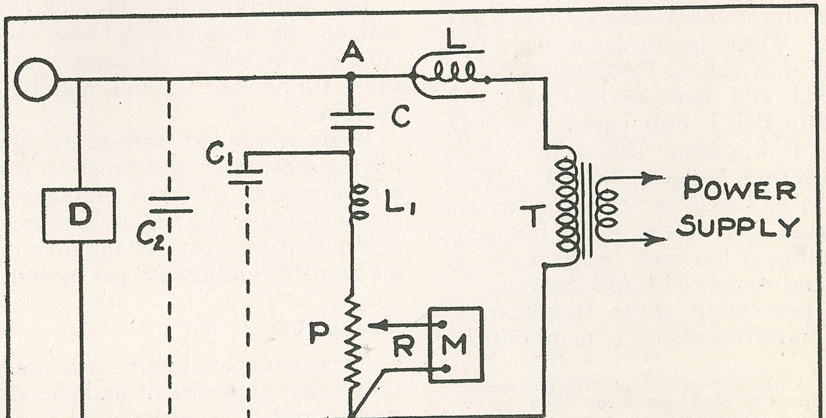
D—Device Under Test

P—Potentiometer, or Tapped Resistor 600 Ohms Resistance, Non-Reactive

L_1—Inductance Between Capacitor and Potentiometer—10 Microhenries, Approximate

C_1—Stray Capacitance on Potentiometer Side—Not Over 50 Micro-Microfarads

C_2—Stray Capacitance on Bus Side—Not Over 60 Micro-Microfarads



Weighting Detector Circuit

This circuit shall include a half wave rectifier and weighting circuit for actuating the indicating instrument. The weighting circuit shall have the following time constants: 10 milliseconds ±20 percent on charge and 600 milliseconds ±20 percent on discharge. The time constants thus specified are the periods required for the voltage (or current) impressed on the indicating instrument to reach 63 percent of its final change following a change in the radio frequency voltage which occurs in less than $^{1}/_{10}$ millisecond.

The time constant of the automatic volume control circuit discussed under Indicating Instrument shall be so short as compared with that of the weighting circuit that the weighting circuit time constants are the determining time constants.

Means shall be provided for switching the indicating instrument from the weighting detector circuit to a conventional detector circuit to be used only for carrier field intensity measurements.

A phone jack shall be provided to permit monitoring the signal while measuring either the field intensity or noise.

Fidelity

The fidelity characteristics of the conventional detector circuit and such additional amplification as may be provided shall be such that the frequency response characteristics will not deviate more than 15 percent from its 1,000 cycle value from 100 to 5,000 cycles with the proper terminating impedance.

The audio amplification shall be sufficient to provide an audible signal in the headphones when a 10 microvolt carrier modulated 30 percent at 400 cycles is applied to the meter.

Indicating Instrument

The indicating instrument shall be of the permanent magnet movable coil type with approximately equal increments of deflection for equal increments of direct current. It shall be provided with a logarithmic scale. The logarithmic characteristic of the radio noise meter shall preferably be obtained in the tubes and circuits of the meter as in conventional automatic volume control circuits as applied to radio receivers.

The indicating instrument shall have a damping factor not less than 10 nor more than 100, as defined in the American Standards Association Standards for Electrical Indicating Instruments C39.1–1938, page 8, item 2.33.

It shall have a time constant not less than 200 milliseconds, nor greater than 500 milliseconds defined and measured as follows: A constant current sufficient to produce about $^{2}/_{3}$ full scale deflection shall be passed through the instrument and the exact final deflection noted. The circuit is then opened and after the pointer comes to rest at zero the circuit is again closed. The time required for the pointer to move from zero to its equilibrium position as previously noted, on the first passage, is the time constant of the indicating instrument as here defined.

The indicating instrument scale should have a length of not less than $3^{1}/_{2}$ inches and should be so calibrated with reference to the characteristic of the circuit of the noise meter that a 10 percent increment of voltage at the noise meter input terminals shall produce not less than $^{1}/_{16}$ of an inch increment of scale deflection within the working range of the scale.

The indicating instrument scale should be calibrated from at least 10 to 1,000 microvolts with the first figured mark at 10, in accordance with data depending upon the noise meter circuit, supplied to the indicating instrument manufacturer. The noise meter circuit should be so designed that the 10 microvolt mark will be located at a point not less than 10 percent of full angular deflection.

Calibrator

The meter shall be provided with a self-contained calibrating signal source. It is recommended that the electron shot noise of a saturated diode be used as the calibrating voltage. The self-contained calibrating source shall be calibrated in terms of a sine wave standard, and shall be capable of maintaining the accuracy of the radio noise meter to within ±15 percent in the frequency range of 540 to 1,600 kc. The accuracy at all other frequencies shall be within ±25 percent.

Weight

It is recommended that the total weight of the noise meter, including self-contained batteries, be less than 35 lbs, when designed for portable use.

Tubes and Batteries

For portable meters the batteries shall be contained within the noise meter case. Tubes and batteries should be of standard, readily procurable types. It is recommended that batteries be of sufficient size to give a life of at least 50 hours on intermittent service of four hours per day.

III—Methods for the Measurement of Radio Noise-Influence Voltage

General

The auxiliary circuits and detailed methods of measurement contained in this report have been developed primarily for the 540–1,600 kc broadcast band. It is probable, however, that the same methods can be used for measurements at frequencies above and below this band, but since the problem of measurement at these other frequencies is now in the developmental stage, the scope of this report as far as detailed measurement procedure is concerned, is limited to the 540–1,600 kc band.

The term "Radio Noise-Influence Voltage" will be used hereafter to designate the radio noise voltage measured with a radio noise meter in accordance with the above specifications at the terminals of electrical apparatus when connected and arranged in accordance with one of the circuits shown in Figs. 1, 2, 3 and 4. This term is used in order to make a definite distinction between this voltage and radio noise voltages measured under other conditions. In the latter case, the measured values will hereafter be referred to as the "Radio Noise Voltage."

The noise voltages produced in radio receivers by electrical apparatus generally result from the transmission of high-frequency currents along the wires or conductors connected to the apparatus. These currents are due to the noise electromotive forces produced by the apparatus. Because the apparatus either is grounded or has a substantial capacitance to ground, the currents will not be confined to the conductors connected to it, but will in addition be propagated by way of the ground. It is, therefore, necessary to consider the disturbing voltages as consisting of two components, one corresponding to the electromotive force acting between the various conductors, hereafter referred to as the line-to-line noise influence voltage (E_L) and the other corresponding to the electromotive force acting between the ground as one pole and the conductors jointly as the other, hereafter referred to as the line-to-ground noise-influence voltage (E_G).

Where equipment has a metal frame capable of being grounded, this frame shall be grounded during the test.

The final reading of the noise meter shall be the mean value as observed during a period of not less than 10 seconds.

In the case of apparatus having

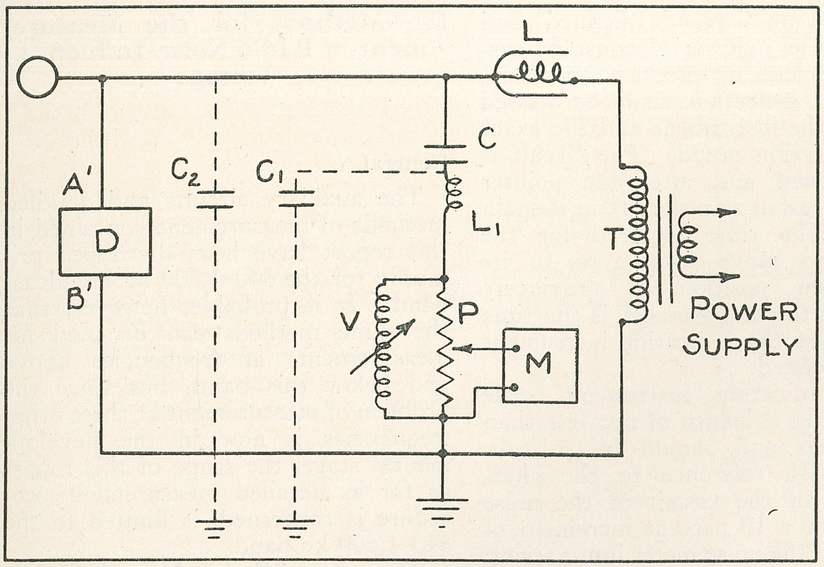


Fig. 4—Compensated Circuit for the Measurement of the Noise-Influence Voltage of High Voltage Devices

T —Testing Transformer
L —R. F. Choke, Not Less Than 20,000 Ohms at Radio Frequency at Which Measurement is Made
M—Radio Noise Meter
C —Coupling Capacitor, Not Less Than 0.0025 mf
D —Device Under Test
P —Potentiometer, or Non-Reactive Tapped Resistor
L_1*—Inductance Between Capacitor and Potentiometer*
C_1*—Stray Capacitance on Potentiometer Side*
C_2*—Stray Capacitance on Bus Side*
V —One Type of Device for Compensating Stray Capacitances C_1 *and* C_2

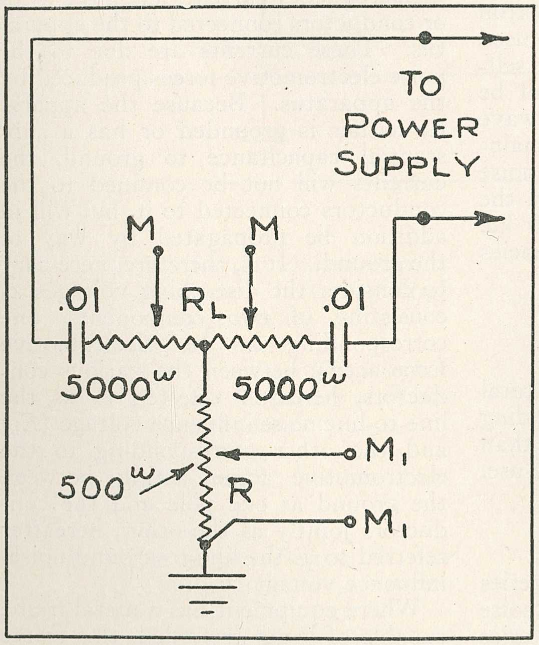


Fig. 6—Circuit for the Measurement of Radio Noise-Voltage on Supply Line in the Field

M-M —Terminals for Line-to-Line Measurements
M_1*-*M_1*—Terminals for Line-to-Ground Measurements*

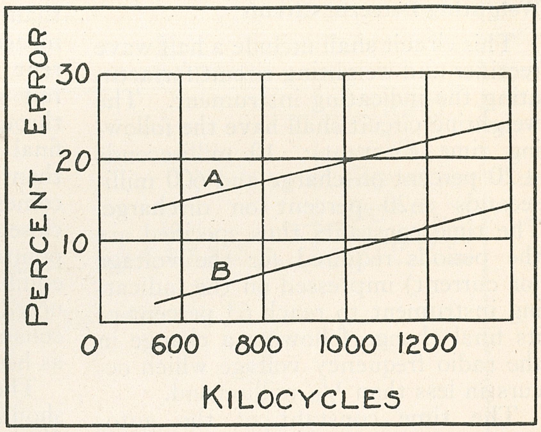


Fig. 5—Error Due to Stray Capacitance Shown in Fig. 3

A. Internal Impedance Equivalent to 200 mmf
B. Internal Impedance Equivalent to 20 mmf

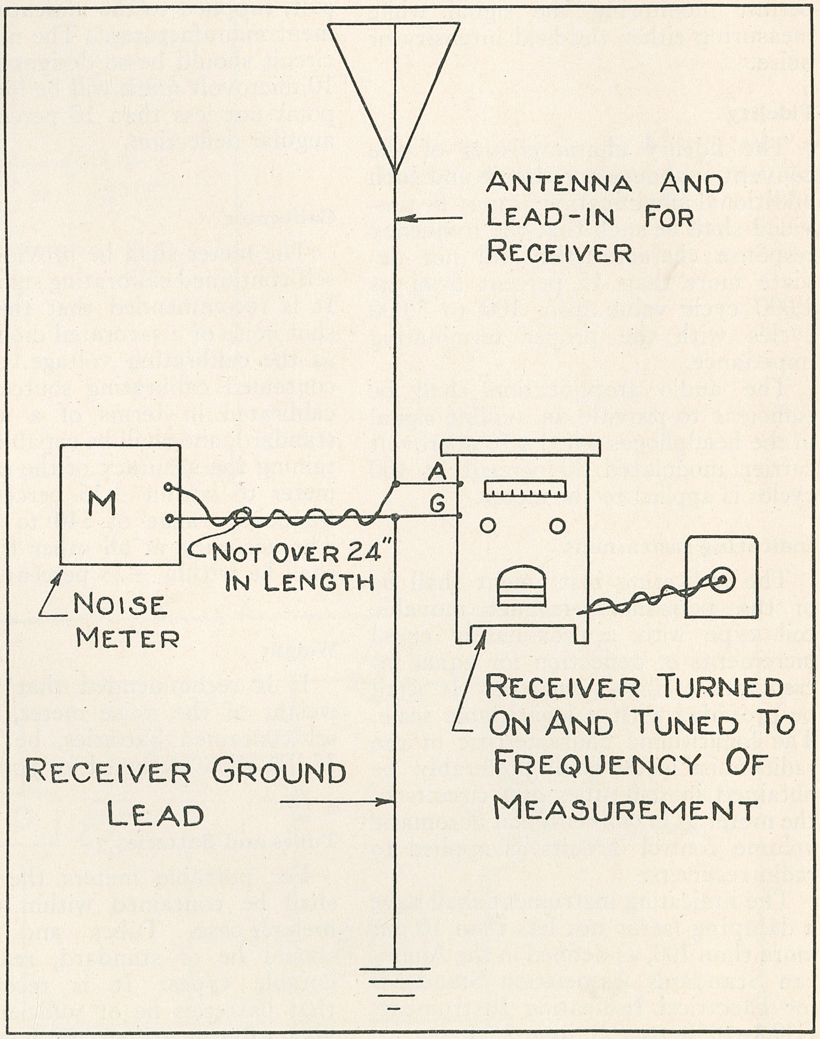

ANTENNA AND LEAD-IN FOR RECEIVER
M
A
G
NOT OVER 24" IN LENGTH
NOISE METER
RECEIVER TURNED ON AND TUNED TO FREQUENCY OF MEASUREMENT
RECEIVER GROUND LEAD

Fig. 7.—Circuit for the Measurement of Radio Noise and Signal Voltages on Antenna of Radio Receiver

radio noise influence of the nature of impulses separated by long intervals, the reading shall be the average of the readings for ten successive impulses.

Networks as shown by Figs. 1, 2 and 6 should be connected to the supply circuit by a pair of leads not more than 24 inches long and to the noise meter by leads not more than 4 inches long.

When only one measurement is made in the broadcast band the reading should be taken at 1,000 kc. When measurements at additional frequencies in the broadcast band are desired readings should be taken at 600 and 1,400 kc and at intervals of 200 kc between these frequencies.

The resistances in the networks of Figs. 1, 2, 3, 4, 6 and 7 must be substantially non-inductive at the radio frequencies employed in the measurements. These resistors may be of the metallized filament or carbon type commonly used in radio receivers. They should preferably be mounted with the coupling capacitors in a non-ferrous metallic case. The resistance values should not differ from those specified by more than ±5 percent. Furthermore, the resistance between one line terminal and the ground terminal should not differ by more than 1 percent from the resistance between the other line terminal and the ground terminal. Taps for suitable ratios can be secured by proper selection of resistor units.

The networks of Figs. 1, 2 and 6 are intended primarily for use on circuits of not more than 150 volts to ground or 300 volts line-to-line. With proper precautions to avoid the possibility of shock and stray capacitance to ground and rugged construction of the elements the same type of network can be used for higher voltages.

Low Voltage Apparatus

A—Single Phase

The measurement of noise-influence voltages of single phase, low voltage apparatus such as motors, appliances, etc., shall be made with the circuit arrangement as shown in Fig. 1. Measurement of the line-to-line voltage (E_L) is made by connecting the radio noise meter across the terminals M—M. This voltage may be obtained by measuring the voltage across a known portion (R_L) of the 600-ohm resistance between lines. The voltage thus measured is multiplied by $\frac{600}{R_L}$ to obtain E_L.

Measurement of the line-to-ground voltage (E_G) is made by connecting the radio noise meter across the terminals M_1—M_1. This voltage may be obtained by measuring the voltage across a known portion (R) of the 450-ohm resistance. The voltage thus measured is multiplied by $\frac{600}{R}$ to obtain E_G.

The radio noise already existing in the supply circuit independently of the apparatus under test should not be included in the measurements and the normal impedances existing between the supply lines and ground should not modify, in any essential respect, the characteristics of the measuring circuit. These two results are achieved by inserting in each supply lead between the measuring circuit and the terminals of the supply line a choke having a radio frequency impedance of not less than 5,000 ohms at the frequency of test. The chokes must be so designed that any drop in the supply voltage due to the load current of the apparatus does not cause the terminal voltage to fall below the normal working range of the apparatus. In some cases, where the supply line noise voltages are large, it may be necessary to use two additional chokes on the supply line side of the blocking capacitors to improve the filtering action and reduce the current in the lead to the midpoint of the blocking capacitors. These chokes need not have a very high impedance, approximately 500 ohms being satisfactory.

B—Three Phase

Fig. 2 shows the arrangement of a network suitable for the measurement of the radio noise influence voltage of low voltage three-phase apparatus. The line-to-line voltage (E_L) is measured across terminals M—M including a known portion (R_L) of the 600-ohm resistance between lines. The voltage thus measured is multiplied by $600/R_L$ to obtain E_L.

The line-to-ground voltage (E_G) is measured across terminals M_1—M_1 including a known portion (R) of the 500 ohm resistance. The voltage thus measured is multiplied by $600/R$ to obtain E_G.

C—Precautions for Testing Apparatus with Frame Ungrounded

It has been the experience to date that it is necessary to ground the device under test if comparable results in various locations are to be obtained. However, for apparatus that is normally ungrounded in service the grounding of the apparatus increases considerably its apparent ability to produce radio noise. It is felt that due to the lack of information on this subject, it is desirable to include in these specifications the precautions to be taken when the apparatus being measured is not grounded.

In order that the capacitance to ground of apparatus tested ungrounded may be standardized for the purpose of measurement, the apparatus under test including the supply cord shall be placed in an insulated position 15 inches above the metallic floor of the test room. The distance to the walls of the room must not be less than 15 inches. The radio noise meter, networks, and the person in charge of the test must be at a distance greater than 15 inches from the apparatus. If a shielded room is not available, the apparatus must be placed at a height of 15 inches over the center of a grounded metal plate which is not less than 7 ft. in diameter.

High Voltage Apparatus

Determination of the radio noise-influence voltage of line apparatus, such as insulators, bushings, and fuse cutouts, shall be made by means of a circuit having a terminating impedance substantially equivalent to 600 ohms resistance at the frequency used for the measurement. Due to the presence of coupling capacitors, stray capacitance between high-voltage parts and ground, etc., precautions must be taken to insure obtaining this impedance and to reduce errors arising in the measuring circuit. Any suitable procedure may be employed, two possible methods being shown in Figs. 3 and 4.

No regulating means shall be used for varying the voltage to the primary of the testing transformer which will produce a distorted voltage wave on the secondary of the testing transformer. A sine wave of acceptable commercial standard as defined in A.S.A. Standard for Rotating Machinery, Section 3.220 shall be applied to the apparatus under test.

Tests shall be conducted under atmospheric conditions prevailing at the time and place of test, but it is recommended that tests be avoided when the vapor pressure exceeds 0.6 of an inch of mercury. Since the effect of humidity and air density upon the radio noise-influence voltage are not definitely known, no correction factors are recommended for either at the present time. However, it is recommended that barometric pressure and dry and wet bulb thermometer readings be recorded so that if suitable correction factors should be determined they could be applied to previous measurements.

A—Ordinary Circuit

In the circuit of Fig. 3 there is no compensation for the effect of stray capacitance between parts of the circuit and ground. When the stray capacitances do not exceed the limits given in Fig. 3, the errors due to the measuring circuit will not exceed those shown for noise sources having the effective impedances indicated by Fig. 5. Two curves are given. The curve marked 20 mmf is for devices with internal series impedances equivalent to a capacitance of 20 mmf, as for instance, an insulator. The other curve is for devices with internal series impedance equivalent to a capacitance of 200 mmf.

B—Compensated Circuit

Many types of compensation may be used to correct for the stray capacitance. One such circuit is shown in Fig. 4. When this circuit is used the stray capacitances need not be limited to the values shown in Fig. 3. Test facilities are necessary for making the adjustments which must be made at the radio frequency at which measurements are to be taken. A variometer V is connected across the resistance potentiometer P and adjusted approximately to the inductance required for parallel resonance with the total stray capacitance $(C_1 + C_2)$. This is only a first approximation since the stray capacitance is distributed.

If desired, another inductance may be added at L_1 for the purpose of tuning out the reactance of the coupling capacitor C. To make the proper adjustments the impedance between A' and B' with the device D removed is measured at the required radio frequency by means of a radio frequency bridge or other suitable means. The variometer V and the total resistance of the potentiometer P are adjusted until this impedance is 600 ohms within ±5 percent. This impedance should be practically equivalent to a resistance. The required resistance of P will generally be higher than 600 ohms because the effective resistance of the variometer V is in parallel with P and because the variometer does not completely eliminate the current through stray capacitance when part of this capacitance is on the line side of the coupling capacitor. However, when the proper value of resistance for P is found, the radio frequency voltage across P will approximate the radio frequency voltage across $A'B'$.

The final adjustment of P is made by connecting an oscillator or signal generator across $A'B'$ (with D removed) and adjusting P until the voltage across it is approximately the voltage across $A'B'$. These voltages may be measured with the radio noise meter for this adjustment. If their difference does not exceed 5 percent, the error in the noise measurement due to the measuring circuit will not exceed that value. When the radio noise meter is connected across P or a portion of P the ratio by which the readings are to be multiplied should be determined by test as described above.

If measurements are to be made at more than one frequency within the broadcast band, the proper inductance of V and resistance of P may be determined initially for each frequency. The variometer V can be provided with a dial on which the settings for different frequencies are marked. The potentiometer P can be provided with taps and a selector switch. The choke L should have an impedance of at least 20,000 ohms at any frequency at which a measurement is made.

IV—Method for the Measurement of Radio Noise Voltage in the Field

It is often desired to measure the radio noise voltage existing on low voltage electrical networks or to measure the radio noise voltage produced by certain apparatus under conditions typifying its normal use. In making such measurements it is essential that the measuring equipment does not change the impedance characteristics of the electrical circuit. Such tests shall be made with the circuit arrangement as shown in Fig. 6. Measurement of the line-to-line voltage E_L is made by connecting the radio noise meter across the terminals M—M. This voltage is obtained by measuring the voltage across a known portion (R_L) of the 10,000-ohm resistance between lines. R_L shall not exceed 1,000 ohms. The voltage thus measured is multiplied by $10{,}000/R_L$ to obtain E_L.

Measurement of the line-to-ground voltage E_G is made by connecting the radio noise meter across the terminals M_1—M_1. This voltage is obtained by measuring the voltage across a known portion R of the 500 ohm resistance. The voltage thus measured is multiplied by $3{,}000/R$ to obtain E_G.

V—Methods for the Measurement of Radio Noise Field Intensities

General

Measurements shall be made with a calibrated instrument conforming to the foregoing specifications. Because of the prevalence of resonance effects and other conditions tending to cause a variation in noise over the wave band under study, measurements should be made at several frequencies whenever possible.

In making field measurements the radio noise meter should rest on the ground or be grounded with a short lead, except where measurements are made with the instrument in an automobile. In this case the instrument should be grounded to the car body and suitable correction factors should be determined as follows: Measure a steady noise with the noise meter on the ground, using the rod antenna; then install the noise meter in the car, mount the antenna rod on the car body and measure the same noise at the same frequency, with the car in such a location that the mounted rod will be in approximately the same vertical line as with the instrument on the ground. The first measurement divided by th second will give an antenna facto which can be used to correct the measurements made with the equipment in the car.

Transmission and Distribution Lines

Measurements of radio noise on overhead transmission lines should be made along the line at a fixed distance, laterally, from the centerline of the supporting structures. Since most disturbances originate on the pole or tower, measurements should be made preferably at a point adjacent to each structure.

Noise measurements should be made only at frequencies where no appreciable station carrier wave interference is obtained. Single frequency measurements should be made at or near 1,000 kc. Additional measurements at approximately 600 and 1,400 kc are desirable. In certain cases, measurements should be obtained at one structure for at least five frequencies between 540 and 1,600 kc.

A change in configuration or elevation of the line will change the coupling between the noise meter and the disturbing circuit. In addition, ground wires, guys, and steel supporting structures will have an influence on the results. Local conditions usually limit the choice of the lateral distance o measurement. For these reasons, [illegible] is essential that data obtained along transmission lines include distances used and other pertinent information.

The measurement of radio noise on distribution circuits should be carried out in a manner similar to that outlined for transmission lines, except that due to the more complex arrangement of distribution circuits and their coupling to various noise sources, greater care must be exercised in the selection of locations for making measurements. Particular notice should be taken o ground leads which tend to shield t vertical rod antenna on the noise meter. In addition, such leads may cause abnormal effects due to the discharge to ground of comparatively large radio frequency currents. Consideration should be given also to conductors at the lower elevations such as service wires, street lamp loops, and others which tend to increase the coupling with the disturbing circuit. As in the case of transmission circuits, pertinent information, consisting of notes and sketches, should accompany data on distribution system measurements.

VI—Measurements at a Radio Receiving Location

The Committee recommends the following measurements and observations at various frequencies:

1. Radio noise voltage on house-wiring circuit in accordance with Fig. 6.
2. Radio noise voltage on antenna normally used with the radio receiver in accordance with Fig. 7. The radio receiver should be turned on but the volume control should be set at the minimum position.
3. Signal voltage of popular broadcasting stations in microvolts measured on antenna for receiver in accordance with Fig. 7.
4. Field intensity in microvolts per meter of the same broadcasting stations, obtained with the radio noise meter standard rod antenna outside of the house and at least 50 feet from buildings and overhead wires.
5. Quality of reception for each station with noise present graded as follows:
    - A. Entirely satisfactory—practically perfect.
    - B. Very good—background unobtrusive.
    - C. Fairly satisfactory—background plainly evident.
    - D. Background very evident, but speech easily understood.
    - E. Speech understandable only with severe concentration.
    - F. Speech unintelligible.

With the foregoing data, notation should be made of the type of house-wiring, that is, armored cable, conduit, non-metallic sheathed cable, or knob and tube wiring, and also the type of antenna system. Some comments relating to the coupling between this antenna system and the house wiring are desirable.

In making the above specified measurements it is realized that the noise in many situations will not be controllable. Consequently, it may not be possible to measure station signal strengths alone. In such cases, useful measurements of a station signal may be made with the noise present, providing the indication of the radio noise meter with noise alone does not exceed 25 percent of the indication with both signal and noise present.

Other Data

In the investigation of complaints and in the study of radio noise effects, there are various other facts which should be determined and noted along with the actual measurements. Some of these are as follows:

1. Stations from which reception is being interfered with.
2. Field intensities of these stations.
3. Make and model of the receiver.
4. Receiver installation—description of antenna, ground, receiver location, distances, etc.
5. Character of the noise—frequency of occurrence, variation in intensity over the broadcast band, and other characteristics.
6. Source of the disturbance and the area covered. State whether the area is urban, suburban, or rural; and if urban, whether in a business or residential section.

VII—Submission of Data

The Committee is desirous of obtaining data on radio noise measurements using apparatus in conformity with the foregoing specifications. Moreover, in order that the many special situations met with in the field may be more fully known, the Committee will appreciate additional data from any observer on measurements where modifications in these methods have been thought desirable. It is hoped that data of the character outlined in this report will be obtained by many observers and submitted to the Committee. The data will be studied and used in the formulation of principles, standards and practices for the reduction of radio noise through coordinated efforts and for working out any improvements found desirable in these specifications. Data should include sufficient detail so that they can be understood and interpreted by the Committee's engineers and should be submitted to the Subcommittee on Collection of Data through the Subcommittee representative of the group furnishing the data or to the Edison Electric Institute, 420 Lexington Avenue, New York, N. Y., The National Electrical Manufacturers Association, 155 East 44th Street, New York, N. Y., or the Radio Manufacturers Association, American Building, 1317 F Street, N.W., Washington, D. C.

This report of the Joint Committee on Radio Reception has been prepared by its Subcommittee on Instruments and Methods of Measurements.

E.E.I. Members

C. S. Young, Pennsylvania Power and Light Company, Allentown, Penna.
H. W. Wahlquist, Edison Electric Institute, 420 Lexington Avenue, New York, N. Y.

NEMA Members

C. V. Aggers, *Chairman*, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Penna.
C. W. Frick, General Electric Company, Schenectady, N. Y.
W. N. Goodwin, Weston Electrical Instrument Company, Newark, N. J.

R.M.A. Members

C. M. Burrill, RCA Manufacturing Company, Inc., Camden, N. J.
D. E. Foster, RCA License Laboratory, 711 Fifth Avenue, New York, N. Y.
P. K. McElroy, General Radio Company, 30 State Street, Cambridge, Mass.
H. J. Schrader, RCA Manufacturing Company, Inc., Camden, N. J.

JOINT COORDINATION COMMITTEE OF RADIO RECEPTION OF E.E.I., NEMA AND R.M.A.

SCOPE: To promote better understanding and cooperation between the several interests concerned with radio reception, including the users of radio equipment, the manufacturers of such equipment, the electric utilities and their consumers and the manufacturers of electrical apparatus and appliances, to the end that the public as a whole may be served in the most efficient manner; to promote the future development and coordination of the electrical arts in such manner as will best serve the public interest; to coordinate the efforts of the several groups represented on this committee and promote joint action in behalf of the objectives before stated; to cooperate with other groups whose interests may be involved; to aid in the establishment of principles and practices relating to radio coordination; to promote the formulation and adoption, through suitable channels, of such codes and standards as may be needed to attain these objectives; to aid and promote the development of proper methods and equipment for use in radio coordination; and to make available to the public from time to time such information as will aid these purposes.

Membership

E.E.I. Members

M. D. Hooven, *Chairman*, Public Service Electric and Gas Company, Newark, N. J.
L. J. Beckwith, The Wisconsin Electric Power Company, Milwaukee, Wis.
J. O'R. Coleman, Edison Electric Institute, 420 Lexington Avenue, New York, N. Y.
W. F. Davidson, Consolidated Edison Co. of New York Inc., New York, N. Y.
H. A. Dambly, Philadelphia Electric Company, Philadelphia, Penna.
H. J. Klumb, Rochester Gas and Electric Corporation, Rochester, N. Y.
C. S. Young, Pennsylvania Power and Light Company, Allentown, Penna.
F. E. Sanford, The Cincinnati Gas and Electric Company, Cincinnati, O.

NEMA Members

H. R. Summerhayes, *Chairman*, General Electric Company, Schenectady, N. Y.
P. L. Alger, General Electric Company, Schenectady, N. Y.
L. W. Chubb, Westinghouse Electric & Manufacturing Company, E. Pittsburgh, Penna.
R. D. Evans, Westinghouse Electric & Manufacturing Company, E. Pittsburgh, Penna.
C. V. Aggers, Westinghouse Electric & Manufacturing Company, E. Pittsburgh, Penna.
A. B. Smith, Automatic Electric Company, 1033 Van Buren Street, Chicago, Ill.
S. H. Mortensen, Allis-Chalmers Manufacturing Company, Milwaukee, Wis.
J. J. Smith, *Secretary*, General Electric Company, Schenectady, New York

R.M.A. Members

L. C. F. Horle, *Chairman*, 90 West Street, New York, N. Y.
D. E. Foster, RCA License Laboratory, 711 Fifth Avenue, New York, N. Y.
E. T. Dickey, RCA Manufacturing Company, Inc., Camden, N. J.
Bond Geddes, Radio Manufacturers Association, 1317 F Street, Washington, D. C.
V. M. Graham, Hygrade Sylvania Corporation, Emporium, Penna.
R. F. Herr, Philadelphia Storage Battery Company, Philadelphia, Penna.
R. A. Hackbusch, Stromberg-Carlson Telephone Manufacturing Company, Toronto, Can.
H. O. Merriman, *Alt.*, Dept. of Transport, Ottawa, Canada
C. E. Kilgour, The Crosley Radio Corporation, Cincinnati, Ohio

SUGGESTED FORMS FOR DATA SHEETS

INSTRUCTION SHEET FOR REPORTING DATA ON RADIO NOISE MEASUREMENTS

General: The following is an explanation of the various items designated on the data sheet for reporting data on radio noise measurements. The purpose and nature of certain items are obvious and require only brief mention.

Space is provided on the first line for inserting the corporate name of the company submitting the data. On this same line a space is provided for inserting a data sheet number. By using consecutive numbers for each report submitted, the sheet number will provide a means of identification and, in the event that more than one data sheet is submitted for a specific case, a different sub-letter can be used with the original sheet number for each additional sheet used.

The item designated as "Location" is included for the purpose of establishing the geographical position where the field data are obtained and should indicate the nearest town or other political sub-division which can be readily identified.

Appropriate spaces are provided for indicating the date of tests, make and serial number of the noise measuring instrument, and persons who made the test. This latter item has been included for the convenience of the company submitting the data if it becomes necessary to refer back to the persons responsible for the information.

Noise Characteristics: Under "Noise Characteristics," the actual cause of the radio noise should be given. If it is of an intermittent nature (starts and stops), the frequency of occurrence over a given period of time and the approximate duration of each noise interval should be recorded.

Physical Data: Items under the sub-heading of "Physical Data" are self-explanatory. Weather conditions are of importance only in those cases where the weather may have some influence on the behavior of the noise.

Receiver Installation: Information is requested on the make and model of radio receiver in the home involved in these tests, and a complete description of the antenna and type of ground should be furnished. Under (c) the type of antenna should be indicated such as indoor, outdoor, vertical, inverted "L," "T," doublet, etc. If the antenna is of the noise reducing type, give make and other identification. Where possible the effective height of the antenna in meters should be given together with the method of determination. The latter can be explained under "Remarks." The type of house wiring should be indicated under (e) as, for example, knob and tube, non-metallic sheath, covered neutral, BX, conduit and others.

Under "f," the minimum distance between the antenna system and the primary supply line should be recorded. Primary supply line refers to the next higher voltage system above the 115/230 v secondary supply line as for example, 2,300 v, 4,000 v, 6,900 v and others. The "Minimum Distance from Antenna to Transmission Circuit" (g) is to be indicated when the source of the disturbance is on the transmission system. In general, where this distance exceeds 200 ft. by direct line, the distance shown should be that along the route of the circuits transmitting the disturbance.

Distribution Line Data: Information requested under the sub-heading of "Distribution Line Data" is self-explanatory. If more than one voltage class of circuit is carried on the pole line all voltages should be given. The item "Length of Parallel between 115/230 volt Supply Circuit and Primary Distribution or Transmission Conductors" is intended to show the degree of coupling with the disturbing circuit or the one transmitting the disturbance from a remote point. In the latter case, sketches should be included to facilitate analysis of the case.

Transmission Line Data: The sub-heading "Transmission Line Data" is intended to cover cases where the source of the disturbance originates on the transmission system. In general, lines above 15 kv phase to phase may be classed as transmission lines.

Remarks: Other pertinent information should be indicated under "Remarks," particularly in cases where additional details must be specified in order to facilitate the correct interpretation of results.

Measurement Data: On the second sheet, space is provided for recording the various data obtained in a particular investigation. At the top of the tabulation, space is provided for recording the time of day at which measurements are made along supply lines and at the receiver location.

Line Noise: The first three columns cover measurements in microvolts per meter made along adjacent overhead supply lines, which may be transmission, distribution or both. The location may be pole number, station or other means of identification. The frequency column should show the radio frequency in kilocycles at which the measurements are made. The approximate distance laterally from the noise meter to the center of the line, an important item, should be given.

Noise-Influence Voltage: Columns 4, 5 and 6 are intended for noise influence voltages obtained in accordance with Figs. 1, 2, 3 or 4 of this *report.* It will be noted that columns are provided for both line to ground and line to line measurements, but it is realized that, in the case of reports involving high voltage apparatus, only line to ground measurements are taken. In many cases it may not be possible to secure noise influence data on the high voltage equipment involved, but such information should be given whenever it is available.

Noise at Receiver Location: Columns 7, 8 and 9 are provided for recording noise voltages as measured on the house wiring system in accordance with Fig. 6. Column 10 is intended for reporting data on noise measurements on the receiver antenna in accordance with Fig. 7.

Station Signal at Receiver Location: The last four columns are reserved for information on station signal measurements and grade of reception. Station signal measurements on the receiver antenna are obtained in accordance with Fig. 7.

Provision is made for recording the field intensity in microvolts per meter of the same broadcasting stations which were measured on the receiver antenna. These measurements should be made with the radio noise meter and standard rod antenna outside of the house and at least 50 ft. from buildings and overhead wires.

The grade of reception mentioned in the last column covering reception of each radio station with the interfering noise present should be designated by letters A to F as follows:

A—Entirely Satisfactory
B—Very Good—Background Unobtrusive
C—Fairly Satisfactory—Background Plainly Evident
D—Background Very Evident But Speech Easily Understood
E—Speech Understandable Only with Severe Concentration
F—Speech Unintelligible

Sketches: The reverse side of the data sheets should be used for the purpose of making sketches which may be of aid in interpreting the data. This is particularly true in connection with the relationship between the receiver antenna and adjacent service wires, either telephone, power or other circuits. Likewise, sketches are considered useful in dealing with any special problem on transmission and distribution circuits. The number of conductors, presence of ground wires, etc., should be shown.

JOINT COORDINATION COMMITTEE ON RADIO RECEPTION
E.E.I-NEMA-R.M.A.

DATA ON RADIO NOISE MEASUREMENTS

Company..Sheet No............
Location..Date..............
Noise Meter..............Ser. No..............Observers...........

Noise Characteristics

(a) Cause..
....
(b) Frequency of Occurrence..................................
(c) Length of Time Present...................................

Physical Data

(a) Urban ( ), Suburban ( ), Rural ( ), (b) Residential Area ( ), Business Area ( ), (c) Weather Conditions..................

Receiver Installation

(a) Make........................(b) Model......................
(c) Description of Antenna...................................
....Effective Height*..m.
(d) Ground......................(e) Type of House Wiring.......
(f) Minimum Distance from Antenna to Primary Supply Line......ft.
(g) Minimum Distance from Antenna to Transmission Circuit......ft.

Distribution Line Data

(a) Voltage......................(b) Single or Three-Phase......
(c) Delta, Unigrounded or Multigrounded Neutral..................
(d) Is Primary and Secondary Neutral Common......................
(e) Length of Parallel between 115/230 volt Supply Circuit and Primary Distribution or Transmission Conductors..........ft.

Transmission Line Data

(a) Voltage (kv Phase to Phase).......(b) Delta or Wye...........
(c) Neutral Grounded.........(d) Overhead Ground Wires..........
(e) Type of Structure (Wood or Steel)............................
(f) Av. Height of Condt. above Ground..........................ft.
(g) Type of Insulators**.......................................
(h) Separation between Trans. and Distribution Conductors........ft.

* Indicate method of calculation or estimating under "Remarks."
** If "Noise Free" pin type, indicate details as to type and other features under "Remarks."

Remarks:

MEASUREMENT DATA

TIME AM TO PM TO AM PM						TIME AM TO PM TO				AM PM			
LINE NOISE			NOISE INFLUENCE VOTAGE			NOISE AT RECEIVER LOCATION				STATION SIGNAL AT RECEIVER LOCATION			
						HOUSE WIRING			RECEIVER ANTENNA				
LOCATION	FREQ.	NOISE	FREQ.	L-G	L-L	FREQ.	L-G	L-L		STA.	RECEIVER ANTENNA	FIELD INTEN.	GRADE OF RECEPT.